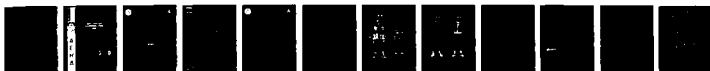
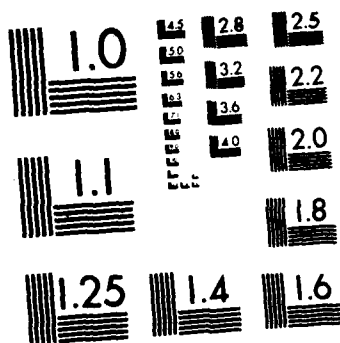


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**UNITED STATES ARMY  
ENVIRONMENTAL HYGIENE  
AGENCY**

**ABERDEEN PROVING GROUND, MD 21010-5422**

**FABRIC/SKIN CONTACT FROM WEARING  
THE ARMY BATTLE DRESS UNIFORM  
STUDY NO. 75-52-0687-88  
JUNE - JULY 1987**

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DEPARTMENT OF THE ARMY  
U. S. ARMY ENVIRONMENTAL HYGIENE AGENCY  
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REPLY TO  
ATTENTION OF

HSHB-MO-T

12 April 1988

MEMORANDUM FOR: Executive Director, Armed Forces Pest Management Board,  
Forest Glen Section, WRAMC, Washington, DC 20307-5001

SUBJECT: Fabric/Skin Contact from Wearing the Army Battle Dress Uniform,  
Study No. 75-52-0687-88, June - July 1987

EXECUTIVE SUMMARY

The purpose and a summary of the pertinent findings of the enclosed report follow:

a. Purpose. To determine what portion of the military battle dress uniform (BDU) actually contacts the skin surface of the wearer so that exposure to fabric impregnants can be quantified.

b. Findings. Of the total fabric used in an average BDU ensemble, only about 42 percent can potentially contact the skin surface of the wearer. The maximum fabric/skin interface area for a medium-regular BDU (no T-shirt or briefs worn) is 2.2 m<sup>2</sup>. The wearing of undergarments significantly reduces the risk of exposure to fabric impregnants.

FOR THE COMMANDER:

Encl

MAURICE H. WEEKS  
Chief, Toxicology Division

CF:

HQDA(DASG-PSP-E) (w/o encl)

Comdt, AHS, ATTN: HSHA-IPM (w/encl)

Dir, Advisory Cen Div Tox, NRC (2 cy) (w/encl)

USDA, ARS, Southern Region (w/encl)

USDA, ARS (Dr. Terrence McGovern) (w/encl)

Defense Technical Information Center (w/encl)

Cdr, USAMRDC, ATTN: SGRD-DPM/LTC Roberts (w/encl)

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			Clothing Fabric/Skin Interface		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) <b>(Sq. m)</b> Military fabrics are routinely treated with substances to extend their useful life expectancy, and with clothing, to enhance the well-being of the wearer. Of concern is the leaching out of impregnants and their availability for skin absorption. Prediction of dose in man requires the quantitation of the skin/fabric interface. The present study determined the fabric/skin contact area by dressing a mannequin in the standard issue Battle Dress Uniform (BDU) then removing all doubled or overlapping fabric. The remaining single thickness fabric was considered that portion available for skin contact. Results showed that while an average BDU ensemble (coat and trousers) contains about 5.7 m <sup>2</sup> of fabric, only about 2.2 m <sup>2</sup> could potentially contact the skin surface of the wearer. This would be reduced further to 1.3 m <sup>2</sup> if undergarments including T-shirt and briefs were worn.					
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REPLY TO  
ATTENTION OF

DEPARTMENT OF THE ARMY  
U.S. ARMY ENVIRONMENTAL HYGIENE AGENCY  
ABERDEEN PROVING GROUND, MARYLAND 21010-5422



HSHB-MO-T

FABRIC/SKIN CONTACT FROM WEARING  
THE ARMY BATTLE DRESS UNIFORM  
STUDY NO. 75-52-0687-88  
JUNE - JULY 1987

1. AUTHORITY.

a. Memorandum of Understanding between the U.S. Army Environmental Hygiene Agency; the U.S. Army Health Services Command; the Department of the Army, Office of The Surgeon General; the Armed Forces Pest Management Board; and the U.S. Department of Agriculture, Agriculture Research, Science and Education Administration; titled Coordination of Biological and Toxicological Testing of Pesticides, effective 23 January 1979.

b. 1st Ind, HQDA(DASG-PSP), 1 May 1987, to letter, Armed Forces Pest Management Board, AFPMB, 27 April 1987, subject: Request for Laboratory Studies on Permethrin.

2. PURPOSE. The purpose of the investigation was to determine what portion of the military battle dress uniform (BDU) actually contacts the skin surface of the wearer so that exposure to fabric impregnants could be quantified.

3. BACKGROUND. Military fabrics are routinely treated with substances to extend their useful life expectancy, and in the case of clothing, to enhance the well-being of the wearer. Treatments may include fungicides, pesticides, fire retardants, water repellents and sizing materials. Of concern is the leaching out of impregnants during normal wear and their possible skin absorption. One substance of interest, permethrin, is an insecticide proposed for impregnation into military BDUs against disease-bearing insects. While the material is considered relatively non-toxic to mammals, predicted health effects in man requires an accurate measure of impregnant availability from the clothing. It has been hypothesized that between 2 and 6 m<sup>2</sup> of the fabric would contact the skin if an average size BDU ensemble was worn. Clearly, the disparity in these figures and the lack of supporting "hard data" severely limits any estimates regarding the fabric/skin interface. Although this study was initiated to provide information for predicting health effects from wearing permethrin-impregnated BDUs, the data is applicable to other clothing treatments.

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4. MATERIALS. Three complete sets (coat and trousers) of the standard issue US Army BDU were obtained from the local Post Exchange. All were medium-regular in size and made from 50-50 nylon/cotton (NYCO) fabric as described in military specification MIL-C-44031B (Class 1). The stock number (SN) appearing on the coat labels read 8415-01-084-1647; and on the trousers, 8415-01-084-1713. Standard issue, 100 percent cotton T-shirts (SN 8420-01-112-1475), briefs (SN 8420-01-112-1959), and socks (SN 8440-00-543-7774) were also obtained. A "male" mannequin was provided by the Physical Protection Division, Chemical Research, Development and Engineering Center, Aberdeen Proving Ground, MD.

#### 5. METHODS.

a. Coats and trousers were individually weighed (following removal of all buttons) using an electronic balance. The mannequin was then dressed, first with undergarments, then the complete BDU. Field boots were put on and the trouser legs bloused. Areas of overlapping fabric, e.g., the coat below the belt line, were marked for later removal (Figure 1). The BDU was then removed from the mannequin and all doubled or overlapping fabric was cut away. Basically, this included all doubled seams, patch pockets and flaps, cuffs, collar, belt loops and reinforced seat, thigh, and elbows. Since the coat fabric below the belt line, as well as the lapels and most of the collar, would not normally contact the skin surface, they were completely removed. The remaining single thickness coat and trousers were weighed and again placed on the mannequin (Figure 2). The outline of the T-shirt and briefs was marked (Figure 2), cut out, and weighed. The bloused trouser legs overlying the socks and rolled up sleeves (to just above the elbow) were similarly measured.

b. The mean ( $n=65$ ) gram weight of  $50 \text{ cm}^2$  swatches of NYCO fabric was earlier determined. Using that value,  $50 \text{ cm}^2 = 1.22 \text{ g} (\pm 0.02 \text{ g})$ , the weight of each section of fabric was easily converted to a measure of area.

#### 6. RESULTS.

a. The results of three replicate measurements for medium-regular BDUs made of NYCO are presented in the Table. Individual measurements appear in the Appendix.

b. The standard issue BDU ensemble contains about  $5.72 \text{ m}^2$  of fabric. After removal of all cloth which could not possibly contact the skin surface,  $2.43 \text{ m}^2$  remains. If undergarments including briefs, T-shirt and socks are worn,  $1.29 \text{ m}^2$  of BDU remains available for direct skin contact.

#### 7. DISCUSSION.

a. The prediction of health effects from exposure to treated fabrics requires a knowledge of the skin/fabric interface, migration rate of the substance from the cloth, the rate of dermal absorption, and the systemic toxicity of the substance. The present study has quantitated the fabric/skin interface in terms of fabric availability for skin contact. This information, coupled with the migration rate, provides a basis for exposure quantitation. It further projects a maximal exposure value since the

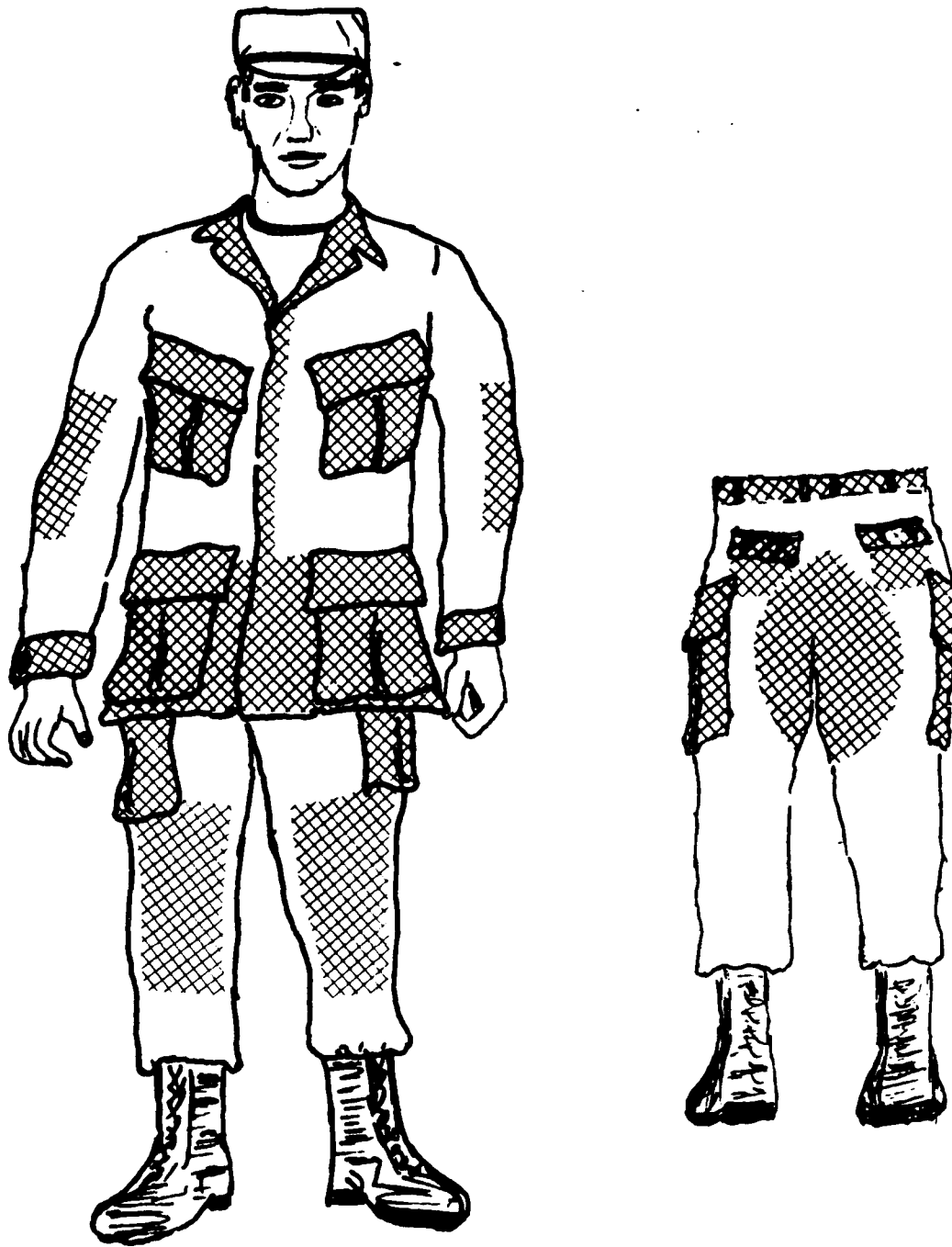


Figure 1. Complete Battle Dress Uniform (BDU). Shaded areas represent overlapping or doubled fabric.

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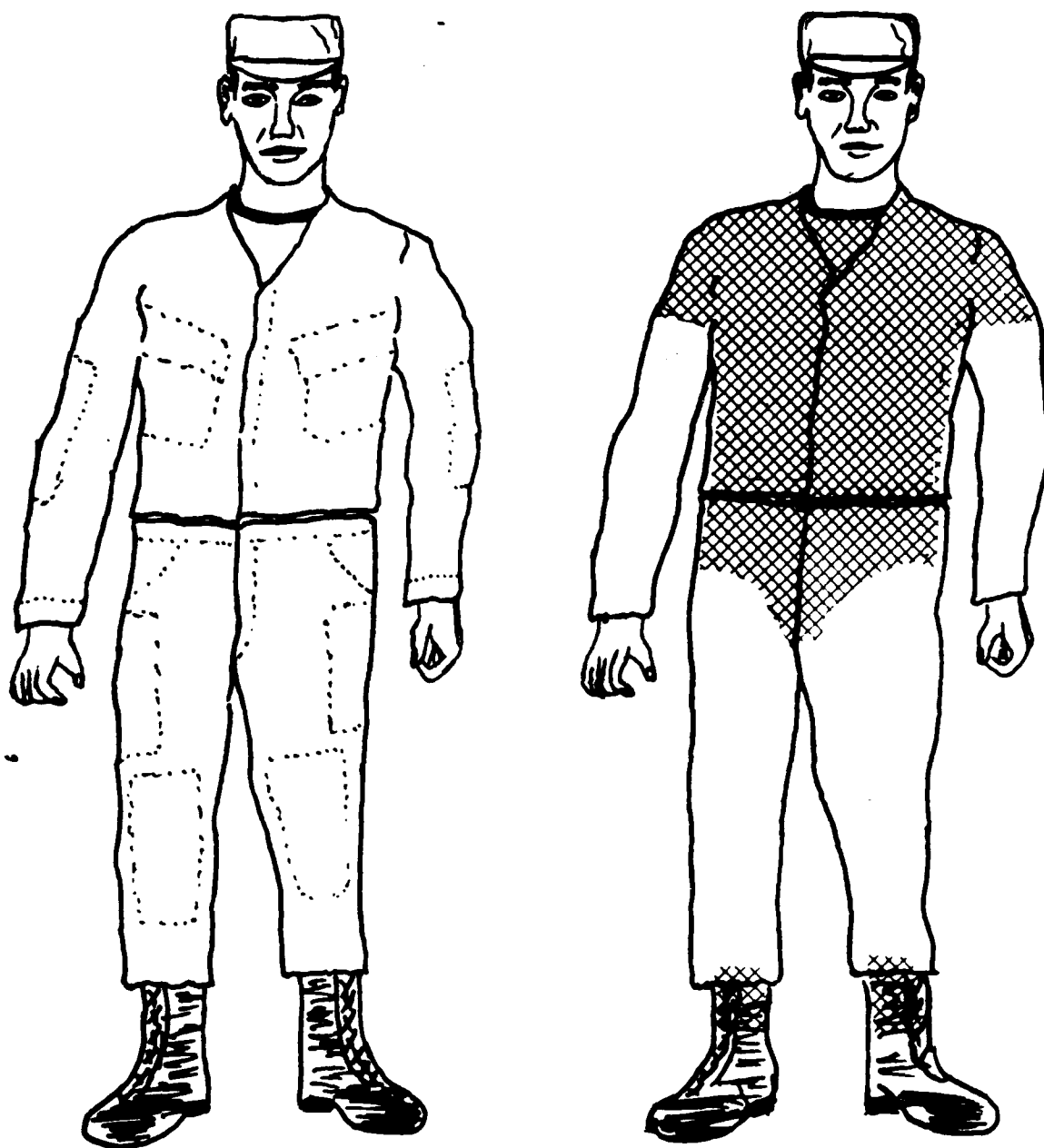


Figure 2. "Trimmed" BDU Following Removal of Overlaying Fabric (left).  
Skin Surface Protected by Undergarments (right).

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TABLE. FABRIC AREA IN MEDIUM-REGULAR BDU's AVAILABLE FOR SKIN CONTACT BASED UPON THREE REPLICATE MEASUREMENTS.

Description	Mean m <sup>2</sup> of Fabric (S.D.)	
Standard Issue Coat	2.71	(0.06)
Available for Skin Contact*	1.12	(0.05)
If T-Shirt Worn, subtract	0.62	(0.04)
If Sleeves Rolled Up, subtract	0.37	(0.02)
Standard Issue Trousers	3.01	(0.03)
Available for Skin Contact*	1.31	(0.03)
If Briefs Worn, subtract	0.30	(0.01)
If Socks Worn, subtract	0.22	(0.01)

\* After removal of overlapping and/or doubled fabric.

likelihood of intimate contact with all the available fabric is remote, given the loose-fitting nature of the BDU uniform. The present study did not consider the cap in estimating skin contact because, due to its construction, it was considered impenetrable to biting insects. It may, however, be important when considering other, nonrepellent substances.

b. Migration of impregnants out of cloth is influenced by the binding ability of the substance to cloth fibers, temperature and humidity, sweating, and natural decay of the impregnant due to weathering or washing. From a health effects aspect, the environmental conditions and possible sweating are of particular concern because they also affect the sorptive ability of the skin. Tropical conditions would, therefore, tend to maximize the health risk of wearing impregnated uniforms. Interestingly, while the skin absorption of most materials is generally higher in hot climates, the toxicity of some insecticides, e.g., DDT and permethrin, is actually decreased<sup>†</sup>. Since dermal penetration is the obvious portal of entry for contact substances, information regarding rate of absorption is necessary in relating this to systemic toxicity, assuming that direct irritation or sensitization is not the issue.

c. The anatomical area of exposure is also a factor in estimating the effects of wearing treated fabrics. The scrotal area is far more likely to absorb topical substances than areas such as the thigh or the back<sup>†</sup>.

<sup>†</sup>Casida, J.E., "Pyrethrum Flowers and Pyrethroid Insecticides," Environmental Health Perspectives Vol. 34, 189-202, 1980.

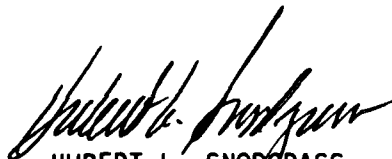
<sup>†</sup>Feldman, R.J. and H.I. Maibach, "Regional Variation in Percutaneous Penetration of <sup>14</sup>C Hydrocortisone in Man," J. Invest. Dermatol., 48, 181-183, 1967.

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Accordingly, the wearing of undergarments becomes extremely practical for individual protection. While socks would almost certainly be worn, underpants (briefs or shorts) are often discarded in hot climates due to actual or feared dermatological conditions. The wearing of T-shirts is also uncertain. It follows then that a conservative projection for BDU fabric/skin contact would be 2.2 m<sup>2</sup> for a medium-regular BDU, if socks were the only undergarments worn.

d. Clearly, the present study is limited in that it evaluates a single BDU size (med-reg). However, the exposure dose to treated fabric, when computed in mg impregnant/kg body weight, should remain relatively constant, regardless of the uniform's size. That is to say that the larger uniform size, containing more fabric area, would be offset by the higher (divisible) body weight. Conversely, the smaller, lighter weight individual would benefit in that the BDU fabric exposure area would be lessened.

8. CONCLUSIONS. It is concluded that of the total fabric used in an average BDU ensemble, only about 42% can potentially contact the skin surface of the wearer. The maximum fabric/skin interface area for a medium-regular BDU (no T-shirt or briefs) is 2.2 m<sup>2</sup>. The wearing of undergarments significantly reduces the risk of exposure to fabric impregnants.

  
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Biologist  
Toxicology Division

APPROVED:

  
MAURICE H. WEEKS  
Chief, Toxicology Division

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# APPENDIX

## INDIVIDUAL BDU MEASUREMENTS

Coat		Complete*	Trimmed	Overlying T-Shirt	Sleeves Rolled Up
A	gram wght	677	284	158	92
	m <sup>2</sup> †	2.77	1.16	0.65	0.38
B	gram wght	646	262	140	85
	m <sup>2</sup>	2.65	1.07	0.57	0.35
C	gram wght	663	274	153	95
	m <sup>2</sup>	2.72	1.12	0.63	0.39

Trousers		Complete*	Trimmed	Overlying Briefs	Overlying Socks
A	gram wght	731	314	72	55
	m <sup>2</sup> †	3.00	1.29	0.30	0.22
B	gram wght	729	318	73	57
	m <sup>2</sup>	2.99	1.30	0.30	0.23
C	gram wght	743	328	70	52
	m <sup>2</sup>	3.05	1.34	0.29	0.21

\* Without buttons.

† Based upon 50 cm<sup>2</sup> of NYCO fabric = 1.22 g ( $\pm$  0.02 g)

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